Promoting Real-Time Science in the Classroom Using Wireless PDA Technology

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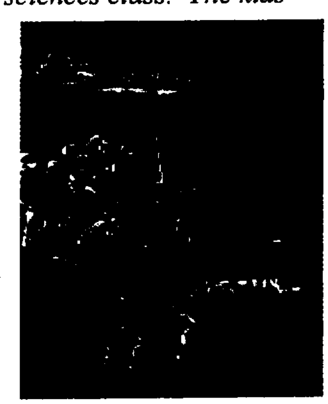
Abstract

The year is 2004, NASA has landed and deployed a fleet of rovers on the surface of Mars to continue the exploration of that planet and prepare the way for human visitors. Middle school students at Milton Elementary have been following the mission through the media and Internet as part of Mr. Johnson's Earth and space sciences class. The kids have been working in teams to track the rovers as they move across the surface of Mars on a scale model of the landing site they built from sand and rocks using pictures and video downloaded from the Internet. They also built their own version of a rover that can be driven around the model. The time is 3:30pm. Jim and a couple of his fellow students from class are sitting in the cafeteria waiting for a student council meeting to begin. Mary and several others are on the bus riding home. Kathy is in her father's car waiting to leave the parking lot. On Mars, Rover-3 has just stopped and issued an alert to ground control at NASA's Jet Propulsion Laboratory (JPL). Back at Milton Elementary chimes can



[1] Submitted as a "white paper" for the MICCA 2002 education conference in Baltimore, MD. http://www.miccaonline.org/

be heard going off in the cafeteria, on the school bus, and in Kathy's car. The students are familiar with the drill and each brings up the Mars mission status display on their handheld PDA device. They've been using their PDAs (those Palm devices that seem to be everywhere today) to obtain real-time position information for each of the rovers throughout the mission. The mission status display tells them that Rover-3 has stopped on the edge of a small gully and isn't quite sure what to do. The students begin considering the options amongst themselves. Should the rover just drive through the gully? If it does, what happens if it gets stuck? Maybe it should turnaround and look for a way around the gully? Tough questions. Real questions. Real problems. The students know they will need to be prepared to discuss the options and conduct their own simulations using the models they built in Mr. Johnson's class tomorrow. Much the same way engineers and scientists will be working to solve the problem at NASA. It's a couple of days later, NASA has made a decision on what to do and has issued new commands for Rover-3 to execute at 9:15am Milton Elementary time. Interestingly, NASA's solution to the problem differs from the one favored by the students. 9:16am, chimes can be heard going off throughout Milton Elementary...

Can it happen? You bet.

The role of technology, doing things in new ways, is critical to the education and development of students. Technology offers new avenues for teachers and students alike to explore and create opportunities for learning, bring excitement into the classroom, extend the classroom beyond its physical limitations, broaden the educational experience of students, and help students become their own teachers. The use of **Personal Digital Assistants** (PDA) devices (Palms, etc.) can support these roles by offering students mobility (the tool goes with them, they don't go to the tool), and access to real-time information (students have access to *information* as it is created, they don't have to wait for it to be made available after the fact). Together, NASA's Goddard Space Flight Center (in Greenbelt MD.) and The Odyssey School (in Baltimore MD.) have been integrating existing PDA technologies and developing new technologies within the classroom, packaging these within lesson plans, classroom activities, and student projects, that can help make the scenario described above and others a reality in our classrooms.

Background

In the fall of 2000, engineers at the Goddard Space Flight Center (GSFC) developed a concept for using wireless PDA technology to help educators teach real-time science in the classroom. The project is called the HAndheld Mars EXploration (HAMEX) project, and its end goal is to use these wireless PDAs for real-time science discovery in concert with the rovers exploring Mars in 2004. To this end, working with the Odyssey School, the GSFC team developed an application that would lead a student in understanding the geo-spatial concepts of latitude and longitude.

To begin, a sample application was developed for the Palm 7x platform (a specific model of the Palm handheld devices that can provide real-time wireless communications). This application enables students to access real-time International Space Station (ISS) data and leads students through exercises dealing with tracking the orbital position of the ISS. An integrated science and social studies lesson plan was developed for middle school students to accompany this and other PDA applications. Middle school students and teachers at the Odyssey School field-tested the lesson plan and the PDA-enabled technologies for effectiveness offering the GSFC experimenters valuable insight and feedback for their research.

This paper will first discuss details of the experiment with the Odyssey School, present and discuss the results of the experiment, provide an overview of the technology used in the experiment, and finally discuss the HAMEX vision for the near future.

Experiment

During the summer of 2001, collaboration was begun between the research engineers at NASA/GSFC and teachers at the Odyssey School. The collaboration sought to achieve goals for both groups. The NASA engineers wanted to demonstrate the feasibility of utilizing real-time science data in a remote environment through unique applications resident on hand held devices (PDAs, and in particular, Palm devices). The Odyssey teachers wanted to demonstrate the potential benefits to their students in using these hand held devices in the learning environment.

The Palm device itself carries enough capability out-of-the-box to be effectively utilized by students under the direction of their teachers. Examples include using the devices to assign homework, manage course schedules, activity lists, etc. But working with the NASA engineers the idea was to extend these basic functions with some specific applications that were tied to more focussed lesson plans. Doing things in new ways is a critical component of student education. The technologies, such as PDAs, help to offer new avenues for students and teachers alike. Additionally, such technology can bring excitement into the classroom by extending the classroom beyond its physical limitations. It broadens the educational experience of students and helps them become their own teachers.

The NASA research engineers at GSFC have been pursuing the development of new technology applications for the *wireless* Palm platform (the Palm 7x model). These applications are targeted at engineers and scientists as well as for use in the classroom. The mobility of the wireless Palm device, which provides access to real-time (on-demand) information, offers a unique combination of capabilities and technologies that allow the needs of all these groups to be addressed simultaneously.

The partnership between the Odyssey faculty and staff with the research engineers at GSFC is aimed at combining both their efforts in utilizing PDA technology. The experiment integrates the ISS application[2] within the middle school science and social studies curriculums being taught at Odyssey. To accomplish this, the school purchased ten Palm 7x handheld devices and real-time network service for a targeted class.

[2] The ISS application is further described in the Technology section.

Beginning in early September 2001, the Odyssey "Brigantines" (the selected 8th grade class) participated in a 3-month trial program involving the use of these technologies and the procured hardware. The devices were used by the students at school and at home to support a number of curriculum-based applications and lesson plans co-developed by GSFC and Odyssey personnel. Additionally, students were trained in the use of the Palm's classic functions to support such things as the date book for class schedules, the to-do list for recording and tracking homework assignments, the memo pad for taking notes, and the address book to store the Odyssey directory. A language component was also added to the Palm and students kept journals of their experiences using these devices. These journals complemented interviews conducted with the students and teachers participating in the program and supported the overall evaluation of the effectiveness of this technology by GSFC and Odyssey.

> **The Odyssey School in Baltimore Md.**[3]
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> The Odyssey school in Baltimore is a small school, grades 1 through 8, for children with dyslexia and other language based learning differences.
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> Odyssey has been considering the use of PDAs as student aids both in and out of the classroom. Dyslexic children have special needs not addressed by traditional teaching techniques and tools. Using the capabilities inherent to PDAs and extending these capabilities to meet the specific needs of dyslexic students have the potential to greatly impact the ability of these students to perform in the classroom. Beyond the classroom and as students graduate and move on to bigger and better things these same technologies will go where the student goes, offering the potential of lifelong aids to support these individuals.

At Odyssey, the PDA was targeted for use in both the social studies and science curriculums. In social studies, the PDA was used essentially as a stand-alone tool to support geography lessons related to the concepts of latitude and longitude. In science class, the PDA complimented a study on ecosystems through a so-called "Farming in Space" activity developed by the Wheeling Jesuit University[4]. This activity introduced students to the concept of the ISS as an ecosystem, and the ability of astronauts on the ISS to grow their own food. The science class used the ISS as a segue from a study of the ecosystem to a study of the physics of motion, in particular, orbital motion.

The following list provides the specific details of the lesson plan developed for the trial program, as well as additional steps that were taken to orient the Odyssey students and prepare them for the use of PDAs in their classrooms.

<u>Preparing for the use of the PDA technologies</u>

Step 1: Memo sent to parents describing the trial program and the roles of students and parents in the program. It is important to inform the parents that their children will be in possession of school-bought equipment. In the case of this Odyssey

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[3] http://www.theodysseyschool.org/

[4] http://voyager.cet.edu/iss/main.asp

experiment, the students and parents were informed that they would not be held responsible for reimbursement is the devices were lost, stolen, or damaged but that a replacement would not be given.

Step 2: Distribution of Palm 7x PDAs to students and orientation to the trial program being conducted at Odyssey (with parents invited). This allowed for open discussion in the general use of the equipment as well as up front feedback on the trail experiment prior to its commencement.

Step 3: Formal student training and orientation on the general function and use of Palm 7x devices. This was a more "technology focused" session following the general orientation. Basic exercises were performed with the goal being to insure that all students could be expected to operate the devices during the course of the experiment. This included the basics of turning the device on and off, using the stylus pointer to activate applications and enter data, and changing the batteries.

Step 4: Students are trained on the use of Palm 7x classic functions for class schedules, school event schedules, Odyssey directory, homework book, and note keeping. These rudimentary tools would serve to make the devices a common aspect of the student's day.

Step 5: Students begin keeping individual journals of their experiences using the Palm 7x devices. Students maintained these journals throughout the trial program.

Integrating the PDA technologies within the classroom environment

Step 6: Students apply the basic concepts of geography (latitude and longitude) being taught in social studies class by using a Palm hurricane application in class and at home to track hurricane activity in the Atlantic throughout the hurricane season. The basic functionality of the hurricane application is to give the user the real-time coordinates and intensity of an Atlantic hurricane derived from weather tracking data.

Students use personal hurricane tracking sheets to plot the changing position of the hurricanes at home; different colors used to track each storm, different symbols used to track intensity of each storm.

Students discuss the origin and development of hurricanes in science class during this time using tracking information gathered during social studies, videos, and classroom activities.

Step 7: Students key off their "farming in space" activities in science class to expand their understanding of the ISS and further exercise their study of latitude and longitude using the ISS application to track the ISS around the world.

Students used the ISS application to obtain real-time position information for the ISS that they recorded in a table. Using the ISS application, they located the ISS position on the application's world map display. This position was then plotted on a world map. These steps were repeated every 10 minutes or so. This activity was conducted in the classroom using a large wall-mounted world map and as a homework assignment using individual single-page world maps. The activity was repeated over a series of classes and days and students were lead in discussions and asked to consider the meaning of the various ISS groundtrack segments collected over the course of several days in the context of the physical laws of motion.

Students are introduced to the concepts of Newton's laws of motion, gravity and satellite motion through various classroom activities designed to answer the question of "why the ISS track looks the way it does".

The Students concluded the activity by retrieving and plotting ISS positions on a homemade celestial sphere to gain a better understanding of how the ISS moves around the Earth. Using the time the ISS position was recorded, students rotated the Earth to its correct orientation within the celestial sphere and then determined and marked the position of the ISS with a piece of clay on the celestial sphere using the ISS's sub-satellite point. This view of the ISS's orbit around the Earth was compared to and used to explain the ISS groundtrack segments recorded earlier in the activity. Orbital motion of the ISS around the Earth was then compared to the motion of other satellites moving around the Earth, using the PDA application, and finally how the Moon moves around the Earth, the Earth moves around the Sun, the Sun moves around the center of the Milky Way, etc.

Step 8: Evaluation and assessment of results from the trial program are collected from the students and faculty.

Results

The trial experiment at Odyssey, detailed in the previous section, offered many useful insights into the use of PDA devices and real-time science data in a classroom setting. The GSFC researchers were able to gain "field-tested" feedback from actual end-users (the students themselves). From the start, it was hoped that the use of the Palm and the Palm-based real-time applications in the classroom and at home by the students would add a new dimension to the lessons being taught and provide a more exciting experience for the students.

The principal result was to learn that indeed working with real data in real time makes it fun for the student. Real data helps students make the connection between what is happening in class to what is happening in the real world. Furthermore, working with the same tools in the classroom and at home makes it easier on everyone. Teachers no longer have to worry if students have the right kind of computers, Internet access, and the same applications at home as in school, etc. With the PDA device, students always have access to everything they need when they need it.

On-demand access to information in the classroom (and at home) eliminates many of the traditional limitations associated with the classroom. The teacher doesn't have to worry about competing for and scheduling computer resources (which can be difficult to do). Lessons can be conducted when it is appropriate to conduct them, not when the computer lab becomes available. Lessons can be impromptu. Students don't need to huddle around a single computer.

Furthermore, the 8th grade students at Odyssey had no difficulty learning how to use the Palm devices. All of the students were eager to learn the technology and essentially taught themselves how to use the devices on their own time and in short order. In addition, the students quickly realized the capabilities of the devices and took the initiative to use them in a variety of ways both in (e.g., record homework assignments, take notes, use it as a dictionary, calculator, etc.) and out (e.g., games, phone book) of the classroom.

But specifically looking at the trail run at Odyssey, it is important to note that the limited nature of the "real-time" component of the experiment led to a cost issue. The ISS application, along with the hurricane data captured from real-time weather applications were the only tools that the students used that required the internet connection service. Even the discount rate for the trail class (10 devices for 10 students) ran to $100 a month. This on its own is not a major cost burden, but given the fact that it was needed to support just these two parts of the lesson plan calls into question that cost benefit. The mitigation suggested by the Odyssey faculty is to (1) develop more comprehensive programs which involve combinations of Palm-based, hands-on, and more traditional classroom activities; and (2) play an active role in extending the use of the devices across multiple classes and as a general student aid which replaces traditional aids like homework notebooks, calculators, dictionaries, thesaurus, etc. Thus, if a classroom wants to make effective use of the connection costs, a more extended use of the real-time component (more wireless applications, more real-time data requests) is recommended.

The Odyssey staff and students gave further recommendations which included (1) develop activities using the Palm which build upon each other and last an extended period of time; (2) more tightly integrate the Palm applications with the lessons being taught in the classroom, complementing the material contained in textbooks and existing lesson plans; and (3) develop activities that stress all the capabilities (real-time access to data, on-demand access to data, computational abilities, data storage capabilities, internet access, etc.) of the Palm.

To summarize, though, the overall consensus message from Odyssey to NASA is to please develop more applications for the classroom!

Technology

The HAMEX project team decided to choose a ubiquitous technology that would meet the many requirements needed for real-time science data to be delivered to a hardware device. Specifically, the Palm 7x Personal Digital Assistants (PDA) was chosen for the hardware. This PDA runs the Palm OS, a widely used operating system in the PDA community. The Palm 7x PDA specifically offers a wireless technology called "Web Clipping." This technology allows for very quick transmission of data, in a manner similar to the way HTML passes information across the Internet.[6] It is called Web Clipping, because the same data that is passed back and forth across the World Wide Web (WWW or Web) is literally clipped, to remove certain data and most graphics. This allows for a faster transmission, as well as less data across the network.

Making use of this technology, the ISS locator application works in the following manner (see Figure 1). A web clipping application on the Palm offers several choices to the user (i.e. which spacecraft to locate). When the user chooses a spacecraft, a web-clipping request is then sent to the HAMEX server, where a Practical Extraction and Report Language (**Perl**) script interprets the request. The Perl script then sends a Hyper Text Transmission Protocol (**http**) request to the ISS real-time

The HAndheld Mars EXploration (HAMEX) project.[5]

HAMEX is a research effort aimed at the effective use of handheld devices for the world of real-time space discovery. It is primarily funded through a small educational outreach grant from the Goddard Space Flight Center (GSFC) in Greenbelt, MD.

The initial grant (from the GSFC Director's Discretionary Fund) was awarded in the Fall of 2000 and it is hoped that through progressive advances and collaborations with scientists and educators (like those from the Odyssey school) that the project will evolve towards its primary goal of scientific and educational outreach with real-time science data from Mars rovers using handheld devices.

[5] HAMEX Website: http://hamex.gsfc.nasa.gov
[6] Palm Website: http://www.palm.com/wireless/

location website.[7] The longitude and the latitude are then parsed from the returned data, and then sent to the Palm in the form of a web-clipping piece of text.

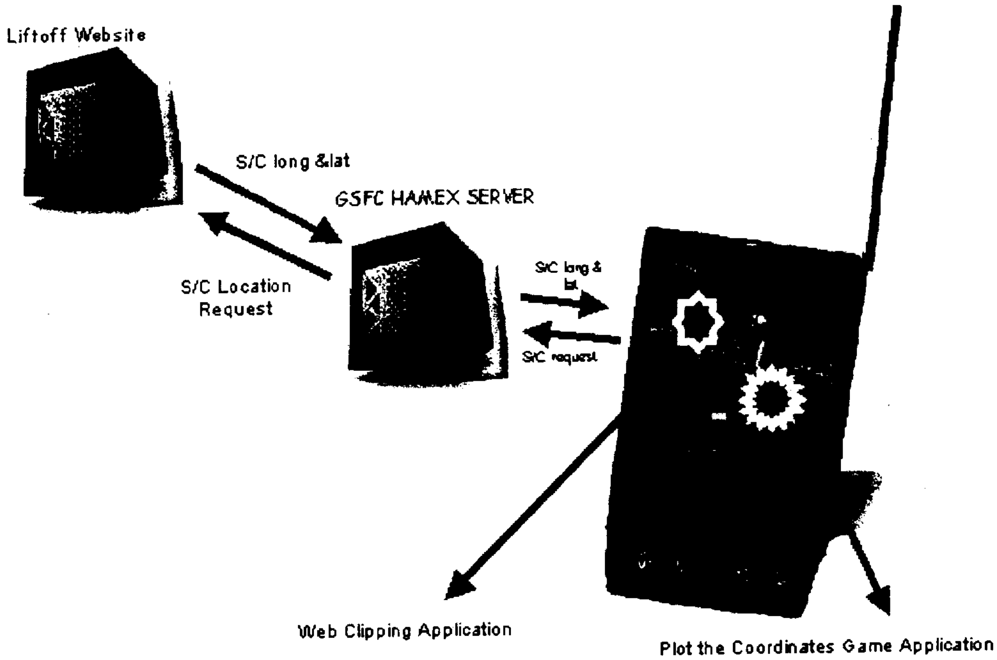

Figure 1 - Prototype Application Architecture

It is at this point when the user can then play the "plot the coordinates" game (see Figure 2). The user clicks on a button which then launches a separate Palm application that allows the user to keep guessing where those selected coordinates are until they hit the correct spot. The application keeps track of the time taken to select the given spot, and who has the current best time.

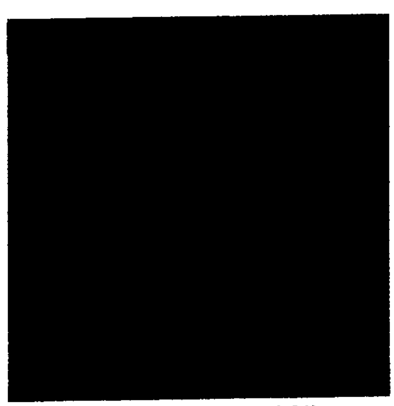

Figure 2 - "Find the ISS" game

[7] Liftoff Website. http://liftoff.msfc.nasa.gov

The plotting game application was written using CodeWarrior Version 7 by MetroWorks.[8] This software allows for easy Palm OS software development by providing an environment for software creation, testing and debugging. One key piece of literature that helped the authors was "The Palm OS Programming Bible" by Foster.[9] This book had numerous examples, and was a good technical reference.

Vision

There are several ideas that would make good next steps towards the future of real-time science in the classroom. Developing a more comprehensive program would better serve the students and the educators. There is a need to develop a full "units" worth of activities built around the use of the Palm, and have them tightly integrated with lesson plans, materials, and textbooks used by the teachers and students. There is a desire to develop future applications that would take advantage of all the Palm has to offer, including real-time access to data, on-demand access to data, handheld computational power, data storage ability, etc. Some possible examples of how the current ISS application might be extended and serve as the basis for a broader, more comprehensive, multi-sensory experience for the students are listed below.

- Use the ISS application (perhaps extended to allow access to more ISS data such as x,y,z position information, x,y,z velocity information, Keplerian elements) essentially as is with students plotting data on world maps and interpreting these data.

- Add an ISS viewing time calculator which would allow the students to take what they've learned about how the ISS moves around the Earth to make predictions of when they can see it and then take their palms outside with them (at home) to actually watch it fly overhead.

- Develop a hands-on activity in which students build their own celestial spheres (using a small globe of the Earth, hamster ball, coffee can, and various bits of hardware) and use these to track ISS positions.

- Develop palm-based activities related to Newton's laws of motion to complement and reinforce information contained in textbooks.

- Develop palm-based applications for use in a lab to measure the acceleration due to gravity (e.g. the standard of dropping stuff and measuring the time it takes to reach various intervals)...these applications would support the collection, storage, and analysis of data generated during the lab.

- Develop a palm-based activity to introduce circular orbital motion. The classic example is the shoot a cannon around the world activity, and it is a favorite for understanding sub-orbital and orbital motion.

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[8] MetroWorks, Inc Website: http://www.metroworks.com

[9] *The Palm OS Programming Bible*, Lonnon R. Foster. IDG Books, 2000

• Develop a palm-based activity to extend beyond the special case of circular orbits to understand the shapes of orbits and how orbits can be changed from one shape to another.

The HAMEX project team hopes that as technology gets further and further along, they will be able to accomplish greater and more helpful applications. As described earlier, the basis for this entire program had developed from the goal of having real-time scientific data accessible from the Rovers which will explore the planet Mars in the 2004 timeframe. The HAMEX team at GSFC is working towards this goal, which is evolving in the years leading up to 2004. As technology advances, the HAMEX team hopes to be able to deliver a handheld application and architecture that will be beneficial to both the scientific community, and the educational community.

For the scientific community, the HAMEX team envisions an application that will allow the scientist to receive data wherever they are using their handheld device, and then be able to make decisions and run other scientific experiments from the handheld communicated back to mission operations. This would free the scientist to be virtually anywhere, doing anything, and still be in contact with the mission.

For the students, the HAMEX team envisions developing a palm-based activity to design a trip to Mars , including defining the steps (breaking a big problem down into several little problems: Earth orbit, transition to Mars orbit, Mars orbit) and setup activities to perform each of these steps. There could be competition to see who can get to Mars the quickest while using the least amount of fuel. Once they get to Mars, they would monitor the rovers just like the scientists, performing their own experiments based on previously developed lesson plans.

As technology continues to advance at the rates recently seen, it seems evident and likely that this vision will be achievable.

Conclusion:

The successful collaboration between the GSFC HAMEX team and the Odyssey School in Baltimore completes the crucial first step in a vision to bring real-time science data into the classroom. By gathering feedback from the "end-user" (the students and their teachers), the researchers and developers of these applications have gained valuable insight into where the next steps should lead. Such success not only benefits the HAMEX team's research, but also the educational community's desire to inspire students and educators using new technologies and real-time science information.

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